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Perioperative Breast MRI Is Not Associated with Lower Locoregional Recurrence Rates in DCIS Patients Treated With or Without Radiation

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Abstract

Introduction—For women with ductal carcinoma in situ (DCIS) undergoing breast-conserving surgery (BCS), the benefit of magnetic resonance imaging (MRI) remains unknown. Here we examine the relationship of MRI and locoregional recurrence (LRR) and contralateral breast cancer (CBC) for DCIS treated with BCS, with and without radiotherapy (RT).

Methods—A total of 2,321 women underwent BCS for DCIS from 1997 to 2010. All underwent mammography, and 596 (26 %) also underwent perioperative MRI; 904 women (39 %) did not receive RT, and 1,391 (61 %) did. Median follow-up was 59 months, and 548 women were followed for 8 years. The relationship between MRI and LRR was examined using multivariable analysis.

Results—There were 184 LRR events; 5- and 8-year LRR rates were 8.5 and 14.6 % (MRI), respectively, and 7.2 and 10.2 % (no-MRI), respectively ($p = 0.52$). LRR was significantly associated with age, menopausal status, margin status, RT, and endocrine therapy. After controlling for these variables and family history, presentation, number of excisions, and time period of surgery, there remained no trend toward association of MRI and lower LRR [hazard ratio (HR) 1.18, 95 % confidence interval (CI) 0.79–1.78, $p = 0.42$]. Restriction of analysis to the no-RT subgroup showed no association of MRI with lower LRR rates (HR 1.36, 95 % CI 0.78–2.39, $p = 0.28$). No difference in 5- or 8-year rates of CBC was seen between the MRI (3.5 and 3.5 %) and no-MRI (3.5 and 5.1 %) groups ($p = 0.86$).

Conclusions—We observed no association between perioperative MRI and lower LRR or CBC rates in patients with DCIS, with or without RT. In the absence of evidence that MRI improves outcomes, the routine perioperative use of MRI for DCIS should be questioned.

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Although ductal carcinoma in situ (DCIS) theoretically has no metastatic potential, substantial ipsilateral breast tumor recurrence (IBTR) rates remain a challenge.¹ DCIS treated with excision alone results in IBTR rates of approximately 28 % at 10 years, and approximately half that (13 %) with excision followed by radiation therapy (RT).² Presumably, IBTR is due to residual, subclinical disease. Recurrence after breast-conserving surgery (BCS) for DCIS is clinically relevant because approximately 50 % of all IBTRs are invasive at time of detection, and invasive recurrences have been shown to increase distant disease and mortality rates.^{2,3}

Four prospective, randomized studies have definitively shown a reduction in IBTR with adjuvant RT [hazard ratio (HR) 0.46, $p < 0.00001$].^{2,4-7} Yet, this reduction in IBTR with radiation has not been accompanied by reduced breast-cancer-specific mortality.² In fact, the Early Breast Cancer Trialists' Collaborative Group overview found women allocated to RT had absolute rates of distant metastases, breast cancer mortality, and all-cause mortality higher than those not receiving RT, although not statistically significant.² Cuzick et al.^{7,8} reported a significant increase in cardiovascular death among women randomized to radiation, although the absolute risk was small (2 vs. 0 %, $p = 0.008$). Other rare but potentially serious risks are also associated with radiation, including second malignancies.^{2,8-12} With no survival benefit, and potential risks, there remains a desire to identify a subset of women for whom radiation could be avoided. A survey of academic radiation oncologists found that most would not recommend RT for some subsets of DCIS, and according to National Cancer Institute Surveillance Epidemiology and End Results (SEER) data, approximately 35–40 % of women undergoing BCS for DCIS in 2005 did not receive RT.^{13,14}

Magnetic resonance imaging (MRI) has been shown to be more sensitive than mammography for the detection of DCIS.^{15,16} Perioperative MRI could identify occult foci of disease or contralateral lesions that would be left unresected with conventional imaging alone. Theoretically, by treating this additional MRI-identified disease, rates of locoregional recurrence (LRR), and contralateral breast cancer (CBC) could be lowered. We undertook this study to examine LRR rates and CBC development in women with DCIS who had undergone perioperative MRI compared to those who did not. Furthermore, we hypothesized that any benefit of MRI would be greater in women not receiving RT and therefore analyzed this subset separately.

METHODS

Following Memorial Sloan-Kettering Cancer Center (MSKCC) institutional review board approval, a prospectively maintained database of women with pure DCIS who underwent BCS at MSKCC was used to identify patients with definitive surgery from 1997 to 2010. Patients with bilateral DCIS were abstracted separately for each side. Twenty women had a diagnosis of synchronous bilateral DCIS. Ten of these women underwent perioperative MRI, and ten did not.

All patients underwent conventional imaging with mammography. Bilateral breast MRI data were collected via chart review. MRI timing was defined as before any biopsy, following

core biopsy, or after lumpectomy but before RT. All outside MRI exam reports were available to the MSKCC breast surgeon, and positive findings were completely evaluated. Age at diagnosis, menopausal status (pre/perimenopausal or postmenopausal), family history of breast cancer (in at least one first- or second-degree relative), prior CBC, clinical (palpable mass, Paget's disease, nipple discharge) versus radiologic presentation, nuclear grade, presence of necrosis, number of excisions, use of adjuvant whole breast RT or endocrine therapy, and margin status [positive (tumor on ink), close (≤ 2 mm), or negative] were recorded. Number of excisions is included because it is likely correlated with extent of radiologically occult disease and has been shown on multivariable analysis to be statistically significantly associated with risk of IBTR for DCIS.¹⁷ For statistical analysis and reporting, positive ($n = 80$) and close margins ($n = 312$) were collapsed into one group. Primary outcomes were ipsilateral LRR rates (IBTR or regional lymph node recurrence) and CBC rates (contralateral invasive or in situ carcinoma identified subsequent to the treatment of the index DCIS). Time-to-event variables were defined as time from final surgery to the event of interest and were censored at time of death or end of follow-up. Patients with previous or synchronous CBC or contralateral prophylactic mastectomy were not included in the calculation of CBC rates. Patients were followed via an annual questionnaire to capture outcomes and treatments obtained outside MSKCC as well as by chart review.

Differences in patient characteristics by use of MRI were assessed using χ^2 tests and Wilcoxon rank-sum tests for categorical and continuous covariates, respectively. Five- and 8-year Kaplan–Meier LRR estimates were calculated for the entire cohort, as well as the subsets with and without RT. Recurrence rates were compared univariately using log-rank tests for categorical covariates. A multivariable Cox model was built to assess the effect of MRI on LRR. Similar multivariable models were built separately for the no-RT and RT groups to confirm that the effect of MRI was similar regardless of RT status. Proportionality of hazards was checked for all three Cox models and found to be appropriate. All statistical analyses were performed in SAS 9.2 (SAS Institute, Inc., Cary, NC), and p values < 0.05 were considered significant.

RESULTS

Between 1997 and 2010, 2,321 women with DCIS underwent definitive BCS, 596 had a perioperative MRI, and 1,725 had conventional imaging alone. The mean age was 57.9 years. Most (66 %) were postmenopausal, and 40 % had family history of breast cancer. Just over 90 % had screen-detected DCIS, 61 % received postoperative RT, and 23 % received adjuvant hormonal therapy. Median follow-up among patients without LRR for the entire population was 59 (range 0–183) months; 548 were followed for at least 8 years. 184 LRR events occurred: 174 isolated IBTR, 2 isolated ipsilateral axillary recurrences, 6 simultaneous IBTR and axillary recurrences, and 2 simultaneous IBTR and distant disease. Of all LRRs, 41.8 % (77/184) were invasive cancer. One patient had IBTR of unknown type with unknown lymph node status, and two patients had unknown lymph node status at the time of invasive IBTR. Two patients developed distant metastasis after invasive IBTR. Overall survival for the entire cohort was 96.9 %.

Patient characteristics by subgroup are summarized in Table 1. Women who underwent MRI were younger, more likely to be pre/perimenopausal, more likely to have a family history of breast cancer, and more likely to present with a clinical abnormality, but were less likely to have a prior CBC. Women in the MRI group were more likely to undergo postoperative RT and treatment with adjuvant endocrine therapy. There were fewer close/positive margins in the MRI group. Patients were more likely to undergo MRI in the later years of the study period. Of all MRIs, 56 % were performed at MSKCC, 12 % were performed elsewhere and reviewed by a MSKCC breast radiologist, and the remainder were obtained and read at an outside institution. Timing of MRI was as follows: 15 % before any biopsy, 66 % following core biopsy, and 19 % following lumpectomy but before RT.

On univariate analysis, there was no difference in LRR rates between conventional imaging and MRI groups ($p = 0.52$). Rates at 5 years were 7.2 % for the no-MRI group and 8.5 % for the MRI group; rates at 8 years were 10.2 and 14.6 %, respectively (Fig. 1a). Variables associated with increased LRR on univariate analysis include younger age ($p < 0.001$), pre/perimenopausal status ($p = 0.001$), close/positive margins ($p = 0.003$), no adjuvant RT ($p < 0.001$), and no adjuvant endocrine therapy ($p < 0.001$; Table 2).

Multivariable analysis of LRR for the 2,212 women with complete data was performed, controlling for age, menopausal status, family history, mode of presentation, margin status, number of excisions, adjuvant RT, adjuvant endocrine therapy, and year of diagnosis. Lower LRR was associated with negative margins and use of adjuvant RT and endocrine therapy ($p = 0.002$). When either age or menopausal status alone were included in the model, each was independently associated with LRR ($p = 0.0005$ and 0.0024 , respectively), but because these variables are highly correlated, when both were included, they competed for significance and became non-significant. Perioperative MRI was not associated with decreased LRR [HR 1.18, 95 % confidence interval (CI) 0.79–1.78, $p = 0.42$; Table 3]. Analyses were repeated after excluding the 20 women with bilateral synchronous DCIS with no significant change in results for any cohort.

No-Radiation Cohort

Analysis was restricted to the 904 women without RT, 174 women underwent MRI, whereas 730 did not. Of those with conventional imaging alone, women in the no-RT cohort were older than those receiving RT (mean age, 62.3 years no-RT vs. 57.3 years RT). Of women having perioperative MRI, those who did or did not have RT were of similar age (mean age, 53.8 years no-RT vs. 53.2 years RT). Within the no-RT cohort, women in the MRI group were younger, more likely to be pre/perimenopausal, and more likely to have a family history of breast cancer compared to the no-MRI group (Table 1).

The 5- and 8-year rates of LRR for the no-RT group were 10 and 13.5 %, respectively, without MRI, and 13.2 and 23.7 %, respectively, with MRI ($p = 0.33$; Fig. 1b). On multivariable analysis, there was no association between MRI and LRR (HR 1.36, 95 % CI 0.78–2.39, $p = 0.28$; Table 3). Margin status was the only variable significantly associated with LRR on both univariate and multivariable analyses.

Radiation Cohort

Among women receiving RT, LRR rates were estimated and compared by MRI group (Fig. 1c), and multivariable analysis was performed (Table 3). There was no association between MRI and LRR (HR 1.14, 95 % CI 0.63–2.09, $p = 0.66$).

Contralateral Breast Cancer

There was no difference in CBC rates with or without MRI in the entire cohort (CBC rate = 3.5 and 3.5 % for the no-MRI and MRI groups, respectively, at 5 years, and 5.1 and 3.5 %, respectively, at 8 years; $p = 0.86$) or in the no-RT ($p = 0.87$) or RT ($p = 0.73$; Fig. 1d–f) subcohorts.

DISCUSSION

MRI is obtained perioperatively with the theoretical benefit of improving surgical planning, decreasing positive margins and the need for re-excision, and identifying clinically and mammographically occult relevant disease. Studies that examine patients with DCIS alone have not shown a decrease in positive margins or the need for re-excision, and some show unnecessary increases in mastectomy rates.^{18–21} In addition, two large, randomized trials have evaluated the addition of preoperative breast MRI in women undergoing BCS for breast carcinoma; one found no difference in reoperation rates (19 vs. 19 %, $p = 0.77$), whereas the other showed a paradoxical increased rate of re-excision among women randomized to MRI.^{22,23} Of note, just over 70 % of the re-excisions in the latter study were for DCIS, suggesting that MRI was relatively insensitive to extent of DCIS.

No prospective, randomized studies have evaluated the effect of MRI on LRR rates. Four retrospective series have addressed the possibility of improved long-term breast cancer outcomes with the addition of perioperative MRI. These studies included few patients with DCIS and even fewer who did not receive radiation (Table 4).^{24–27} Only one study, by Fischer et al.,²⁴ reported reduced IBTR rates with the use of perioperative MRI. This was a retrospective review of 346 patients treated from 1993 to 1997. At a mean follow-up of 40 months, they reported an IBTR rate of 1.2 % in the MRI group and 6.5 % in the no-MRI group ($p < 0.001$). It is important to note that there were significant differences between the groups that were not controlled for. The MRI group had fewer T3/4 tumors, grade 3 or 4 lesions, less lymph node positivity, a higher percentage of DCIS, and, paradoxically, a higher proportion who received chemotherapy.

Three additional studies examining the association of MRI use and long-term outcomes have all failed to find an association between perioperative MRI and decreased LRR rates or improved survival. Solin et al. examined the relationship between MRI and outcomes in 756 women undergoing BCS and radiation from 1992 to 2001. Eight-year local failure rates were 3 % in the MRI group and 4 % in the no-MRI group ($p = 0.51$). For the small subset of patients with DCIS, 8-year rates of LRR were 6 % both with ($n = 31$) and without ($n = 105$) MRI. They found no difference in survival or CBC rates.²⁵ Similar results were reported by Hwang et al.²⁶ (no DCIS patients included) and Shin et al.²⁷ (11 % of population had

DCIS), with no significant difference in LRR rates, at 1.2–1.8 % in the MRI groups versus 2.3–2.5 % in the conventional imaging groups.

Our study is, to our knowledge, the largest evaluating LRR rates with and without perioperative MRI. Furthermore, our population consisted entirely of women undergoing BCS for DCIS, a population for whom local recurrence remains substantial, and for whom metastatic disease or breast cancer mortality is almost zero in the absence of an invasive recurrence. Of all women with breast cancer, those with DCIS could most benefit from a method to select for low risk of local recurrence. Adjuvant radiation and endocrine therapies have proven to reduce local recurrence, but they carry rare but potentially serious risks, and do not improve survival.^{2,7,28} Better definition of subclinical disease could lead to lower LRR rates, and some have shown MRI to be significantly more sensitive than conventional imaging for DCIS.¹⁶

Here, in a large cohort of women with DCIS, we were unable to find any association between improved LRR rates and the use of MRI. Furthermore, although any benefit should be most evident in the group without RT, we found none, and found no trend toward improved LRR rates with MRI.

Detection of a CBC is another argument for the use of MRI in patients with a known cancer. A meta-analysis reported that 4.1 % of women with newly diagnosed invasive breast cancer had CBC detected by MRI.²⁹ Similarly, a study performed on patients with DCIS alone with routine preoperative MRI reported a synchronous CBC rate of 5.6 % (2.1 % invasive carcinoma, 3.5 % DCIS).³⁰ Based on these data, Hollingsworth and Stough³⁰ surmised that metachronous contralateral invasive cancer rates and survival would be impacted by the use of preoperative MRI. Our study found no difference in CBC development rates with or without an MRI, with 5-year rates of 3.5 % in both the MRI and no-MRI groups ($p = 0.86$). These numbers are consistent with SEER data, which reported 5-year CBC rates in patients with DCIS of 3.3 %.³¹ If perioperative MRI were detecting clinically relevant cancers, one would expect a lower rate of subsequent CBC development in those imaged with MRI.

Study strengths include the large number of prospectively collected patients and the considerable number treated without RT. Furthermore, the availability of numerous patient and tumor characteristics made multivariable analysis to control for relevant clinical variables possible. In our population, women receiving MRI tended to be at higher risk for LRR, as seen in Tables 1 and 2. Therefore, we diligently controlled for all possible confounding variables on multivariable analysis to optimally assess the association of MRI and LRR, with inclusion of all variables associated with either MRI use or LRR. Adequate power in multivariable Cox modeling has been described as ten events per variable included.³² This ratio was exceeded in both the entire population and the no-RT cohort. Nevertheless, the analysis remains retrospective, with all associated limitations.

CONCLUSIONS

We found no association between the perioperative use of MRI and LRR in women undergoing BCS for DCIS. In addition, no association between MRI and LRR was found in

the subset that did not receive RT. In the absence of evidence that MRI improves the surgical management or long-term outcomes for these patients, the routine perioperative use of this test should be questioned.

Acknowledgments

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FIG. 1.

Kaplan-Meier ipsilateral locoregional and contralateral breast cancer event-free estimates: **a** entire cohort locoregional recurrence, **b** no-radiation cohort locoregional recurrence, **c** radiation cohort locoregional recurrence, **d** entire cohort contralateral breast cancer, **e** no-radiation cohort contralateral breast cancer, and **f** radiation cohort contralateral breast cancer. *LRR* locoregional recurrence, *CBC* contralateral breast cancer

TABLE 1

Patient, tumor, and treatment characteristics, by use of MRI and radiation

Characteristics	Entire cohort (n = 2,321) ^a			No-radiation cohort (n = 904) ^a			Radiation cohort (n = 1,391) ^a		
	Conventional imaging (n = 1,725) n (%)	MRI (n = 596) n (%)	p value	Conventional imaging (n = 730) n (%)	MRI (n = 174) n (%)	p value	Conventional imaging (n = 976) n (%)	MRI (n = 415) n (%)	p value
Age at surgery, mean years (range)	59.5 (31–92)	53.5 (25–85)	< 0.001	62.3 (31–92)	53.8 (25–80)	< 0.001	57.3 (33–85)	53.2 (27–85)	< 0.001
Menopausal status			< 0.001			< 0.001			< 0.001
Pre/perimenopausal	477 (28.4)	291 (49)		176 (25)	81 (46.8)		297 (31)	208 (50.2)	
Postmenopausal	1,205 (71.6)	303 (51.0)		529 (75.0)	92 (53.2)		662 (69.0)	206 (49.8)	
Family history			0.018			0.048			0.08
Yes	649 (38.1)	259 (43.6)		274 (38.4)	81 (46.6)		365 (37.6)	176 (42.6)	
No	1,054 (61.9)	335 (56.4)		440 (61.6)	93 (53.4)		606 (62.4)	237 (57.4)	
Prior contralateral cancer			0.048			0.540			0.133
Yes	131 (7.6)	31 (5.2)		74 (10.2)	15 (8.6)		54 (5.5)	15 (3.6)	
No	1,591 (92.4)	564 (94.8)		654 (89.8)	159 (91.4)		921 (94.5)	399 (96.4)	
Presentation			0.002			0.055			0.006
Radiologic	1,591 (92.2)	525 (88.1)		668 (91.5)	151 (86.8)		907 (92.9)	367 (88.4)	
Clinical	134 (7.8)	71 (11.9)		62 (8.5)	23 (13.2)		69 (7.1)	48 (11.6)	
Nuclear grade			0.187			0.118			0.352
Low	303 (18.3)	91 (15.5)		209 (30.7)	56 (33.3)		87 (9.1)	33 (8.0)	
Intermediate	761 (46.0)	292 (49.7)		330 (48.5)	89 (53.0)		425 (44.4)	200 (48.5)	
High	591 (35.7)	204 (34.8)		141 (20.7)	23 (13.7)		446 (46.6)	179 (43.4)	
Necrosis			0.082			0.347			0.485
Absent	615 (36.0)	191 (32.1)		386 (53.4)	86 (49.4)		221 (22.9)	102 (24.6)	
Present	1,091 (64)	404 (67.9)		337 (46.6)	88 (50.6)		744 (77.1)	312 (75.4)	
Margin status			0.012			0.004			0.132
Negative	1,412 (82)	515 (86.4)		611 (83.9)	161 (92.5)		790 (80.9)	350 (84.3)	
Close/positive	311 (18)	81 (13.6)		117 (16.1)	13 (7.5)		186 (19.1)	65 (15.7)	
Number of excisions			0.112			0.103			0.678
2	1,587 (92.2)	535 (90.1)		704 (96.8)	164 (94.3)		868 (88.9)	365 (88.2)	

Characteristics	Entire cohort (n = 2,321) ^a			No-radiation cohort (n = 904) ^a			Radiation cohort (n = 1,391) ^a		
	Conventional imaging (n = 1,725) n (%)	MRI (n = 596) n (%)	p value	Conventional imaging (n = 730) n (%)	MRI (n = 174) n (%)	p value	Conventional imaging (n = 976) n (%)	MRI (n = 415) n (%)	p value
3	135 (7.8)	59 (9.9)		23 (3.2)	10 (5.7)		108 (11.1)	49 (11.8)	
Radiation therapy			< 0.001			NA			NA
Yes	976 (57.2)	415 (70.5)		0	0		976 (100)	415 (100)	
No	730 (42.8)	174 (29.5)		730 (100)	174 (100)		0	0	
Endocrine therapy			0.041			0.24			0.744
Yes	380 (22.3)	156 (26.4)		112 (15.4)	39 (22.5)		267 (27.5)	117 (28.3)	
No	1,323 (77.7)	434 (73.6)		615 (84.6)	134 (77.5)		705 (72.5)	296 (71.7)	
Year of surgery			< 0.001			< 0.001			< 0.001
1997–2003	915 (53)	96 (16.1)		414 (56.7)	37 (21.3)		486 (49.8)	56 (13.5)	
2004–2011	810 (47)	500 (83.9)		316 (43.3)	137 (78.7)		490 (50.2)	359 (86.5)	
Median (range) follow-up among patients without LRR, months	69.3 (0–183)	41.1 (1–176)	< 0.001	72.5 (0–181)	44.5 (1–176)	< 0.001	67.9 (0–183)	39.8 (2–144)	< 0.001

^aPatients with missing covariate are excluded

TABLE 2

Locoregional recurrence rates, by patient characteristics and use of radiation

	Entire cohort		No-radiation cohort		Radiation cohort	
	Number of patients	2,321	904	1,391	80	
Number of recurrences	5-year rate	184	104	80		
MRI obtained		0.52		0.33		0.54
Yes	8.54		13.2	6.34		
No	7.23		10	5.22		
Age at surgery		< 0.001		0.038		0.002
< 40	12.31		17.16	9.51		
40–49	10.09		13.94	8.33		
50–59	5.41		7.15	4.52		
60–69	6.74		11.07	4.07		
70+	7.4		9.63	3.63		
Menopausal status		0.001		0.16		< 0.001
Pre/perimenopausal	9.35		13.03	7.51		
Postmenopausal	6.38		9.26	4.34		
Family history		0.37		0.78		0.33
Yes	7.72		9.81	6.47		
No	7.25		10.9	4.91		
Presentation		0.35		0.49		0.69
Radiologic	7.13		10.17	5.23		
Clinical	9.89		12.04	8.13		
Nuclear grade		0.63		0.17		0.21
Low	5.33		7.12	1.06		
Intermediate	6.68		9.42	5.2		
High	8.18		15.08	6.33		
Necrosis		0.5		0.18		0.071
Absent	6.74		8.92	3.5		
Present	7.86		12.15	6.15		

	Entire cohort		No-radiation cohort		Radiation cohort	
	5-year rate	Log-rank <i>p</i> value	5-year rate	Log-rank <i>p</i> value	5-year rate	Log-rank <i>p</i> value
Number of patients	2,321	904	1,391			
Number of recurrences	184	104	80			
Margin status		0.003		< 0.001		0.21
Negative	6.54		8.87		4.99	
Close/positive	11.55		18.83		7.61	
Number of excisions		0.53		0.44		0.25
2	7.24		10.29		5.06	
3	8.89		13.50		7.95	
Radiation therapy		< 0.001				
Yes	5.48		NA		NA	
No	10.42					
Endocrine therapy		< 0.001		0.066		0.004
Yes	4.71		9.42		2.7	
No	8.38		10.62		6.74	
Year of surgery		0.19		0.64		0.34
1997–2003	8.21		11.14		6	
2004–2010	6.08		8.96		4.52	

TABLE 3
Multivariable Cox models for locoregional recurrence, for entire cohort, and those without and with radiation

	Entire cohort (<i>n</i> = 2,212)				No-radiation cohort (<i>n</i> = 853)				Radiation cohort (<i>n</i> = 1,359)			
	n	Number of events	HR (95 % CI)	<i>p</i> value	n	Number of events	HR (95 % CI)	<i>p</i> value	n	Number of events	HR (95 % CI)	<i>p</i> value
MRI obtained				0.42				0.28				0.66
Yes	581	37	1.18 (0.79–1.78)		172	19	1.36 (0.78–2.39)		409	18	1.14 (0.63–2.09)	
No	1,631	139			681	79			950	60		
Age at surgery				0.063				0.39				0.02
Menopausal status				0.48				0.85				0.64
Pre/perimenopausal	752	78	1.18 (0.75–1.83)		250	36	1.06 (0.58–1.94)		502	42	1.18 (0.59–2.33)	
Postmenopausal	1,460	98			603	62			857	36		
Family history				0.5				0.92				0.3
Yes	873	74	1.11 (0.82–1.5)		340	41	1.02 (0.68–1.54)		533	33	1.27 (0.81–2.01)	
No	1,339	102			513	57			826	45		
Presentation				0.8				0.79				0.98
Radiologic	2,017	155			774	85			1,243	70		
Clinical	195	21	1.06 (0.67–1.68)		79	13	1.09 (0.6–1.97)		116	8	1.01 (0.48–2.13)	
Margin status				<0.001				<0.001				0.21
Negative	1,849	131			734	72			1,115	59		
Close/positive	363	45	1.96 (1.39–2.78)		119	26	2.49 (1.56–3.97)		244	19	1.41 (0.83–2.38)	
Number of excisions				0.2				0.41				0.36
2	2,024	156			821	92		1.203	64			
3	188	20	1.37 (0.85–2.2)		32	6	1.43 (0.61–3.31)		156	14	1.31 (0.73–2.37)	
Radiation therapy				<0.001								
Yes	1,359	78					NA				NA	
No	853	98	2.05 (1.5–2.8)									
Endocrine therapy				0.002				0.078				0.007
Yes	526	27			147	13			379	14		
No	1,686	149	1.9 (1.26–2.88)		706	85	1.7 (0.94–3.05)		980	64	2.24 (1.25–4.01)	
Year of surgery				0.38				0.73				0.26

	Entire cohort (<i>n</i> = 2,212)				No-radiation cohort (<i>n</i> = 853)				Radiation cohort (<i>n</i> = 1,359)			
	<i>n</i>	Number of events	HR (95 % CI)	<i>p</i> value	<i>n</i>	Number of events	HR (95 % CI)	<i>p</i> value	<i>n</i>	Number of events	HR (95 % CI)	<i>p</i> value
1997–2003	931	123			411	68			520	55		
2004–2010	1,281	53	0.84 (0.58–1.23)		442	30	0.92 (0.56–1.50)		839	23	0.71 (0.39–1.29)	

Multivariable analysis performed controlling for age, menopausal status, family history of breast cancer, mode of presentation, margin status, number of excisions, radiation (for entire cohort), tamoxifen or other endocrine therapy, and year of surgery. Patients missing one or more covariate are excluded

HR hazard ratio, CI confidence interval

TABLE 4
Summary of literature on association of perioperative MRI and breast cancer locoregional recurrence rates

Author, year	Total patients	DCIS patients N (%)	Patients with MRI N (%)	Patients with DCIS and MRI N (%)	Patients with DCIS without RT N (%)	Variables controlled for on multivariable analysis	Time interval for which LRR reported (years)	Reported LRR		p value
								MRI (%)	No MRI (%)	
Fischer et al. 2004 ²⁴	346	23 (7)	121 (35)	15 (4)	0		3.4	1.2	6.5	< 0.001
Solin et al. 2008 ²⁵	756	136 (18)	215 (28)	31 (4)	0	Age, year	8	3 ^a	3 ^a	0.32
Hwang et al. 2009 ²⁶	463	0	127 (27)	0	0	Age, year, adjuvant chemotherapy/endocrine therapy, tumor grade, LVI, hormone receptor status, HER2 status	8	6 ^b	6 ^b	0.51
Shin et al. 2012 ²⁷	794	87 (11)	572 (72)	62 (8)	13 (2)		5	1.2	2.3	0.33
Current series	2,321	2,321 (100)	596 (26)	596 (26)	904 (39)	Age, menopausal status, family history, presentation, margin status, number excisions, year, RT, endocrine therapy	8	14.6	10.2	0.42

^a 8-year LRR reported for invasive carcinoma

^b 8-year LRR reported for DCIS patients